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Improving Alaska region short-term weather forecast with data assimilation

Jiang Zhu¹, E. Stevens¹, B. T. Zavodsky², X. Zhang³, E. Weisz⁴, J. Cherry¹, and T. Heinrichs¹

¹GINA, University of Alaska,

²Marshall Space Flight Center, NASA,

³International Arctic Research Center, University of Alaska

⁴CIMSS/SSEC/UW-Madison



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Introduction

- Data assimilation has proven to be very useful in improving both global and regional numerical weather prediction (NWP) (e.g. Goldberg et al. 2003, Zavodsky et al. 2012).
- Alaska benefits from more coverage of polar-orbiting satellite passes compared to the lower 48 states.
- The Geographic Information Network of Alaska (GINA) at the University of Alaska began to study satellite data assimilation for the WRF model two years ago. We drive to improve short-term forecast by using data assimilation technology.
- Atmospheric Infrared Sounder (AIRS) and Cross-track Infrared Sounder (CrIS) profile/radiance data were assimilated into a customized Alask regional WRF mode.

Experiment and Methodology

- WRF: the GINA-WRF is setup to cover the entire Alaska area (Fig.2) .
- Parameters: the optimized model physical parameterizations and treatments for the Alaska and Arctic region (Zhang et al. 2013) were employed.
- Data Assimilation Scheme: Community Gridpoint Statistical Interpolation (GSI) system 3-Dvar.
- Experiment: runs WRF in five modes (see Table 1).

Table 1. Running WRF in 5 modes are included in the experiment

Mode/Time	T-12 h	T-6 h	T h
CNTL	Run WPS with GFS output, run WRF to produce 6 hours of forecasts	Run WRF with 6-hour forecast from CNTL T-12h to produce 6 hours of forecasts	Run WRF with 6-hour forecast from CNTL T-6h to produce 48 hours of forecasts
AIRSP	Get output from CNTL WPS at T-12h, do AIRS profile DA, run WRF to produce 6 hours of forecasts	Do AIRS profile DA with 6-hour forecast from AIRSP T-12h, run WRF to produce 6 hours of forecasts	Do AIRS profile DA with 6-hour forecast from AIRSP T-6h, run WRF to produce 48 hours of forecasts
CrISP	Follow the same steps as AIRSP, except using CrIS profile data		
AIRSR	Follow the same steps as AIRSP, except using AIRS radiance data		
CrISR	Follow the same steps as AIRSP, except using CrIS radiance data		

- Data:
 1. GDAS conventional observation data plus best quality AIRS/CrIS retrieved profile data (as determined by Pbest in AIRS and QF5_CrIMSSEDR for CrIS) are used as inputs for the GSI data assimilation scheme.
 2. AIRS/CrIS radiance data.
- Evaluation technology: forecast outputs are compared against “Ground True” conventional point observation data by using matched pairs selected by Model Evaluation Tools (MET). RMSE for all modes are calculated to quantify the impact of data assimilation.

Results-cold air aloft at 2014022412

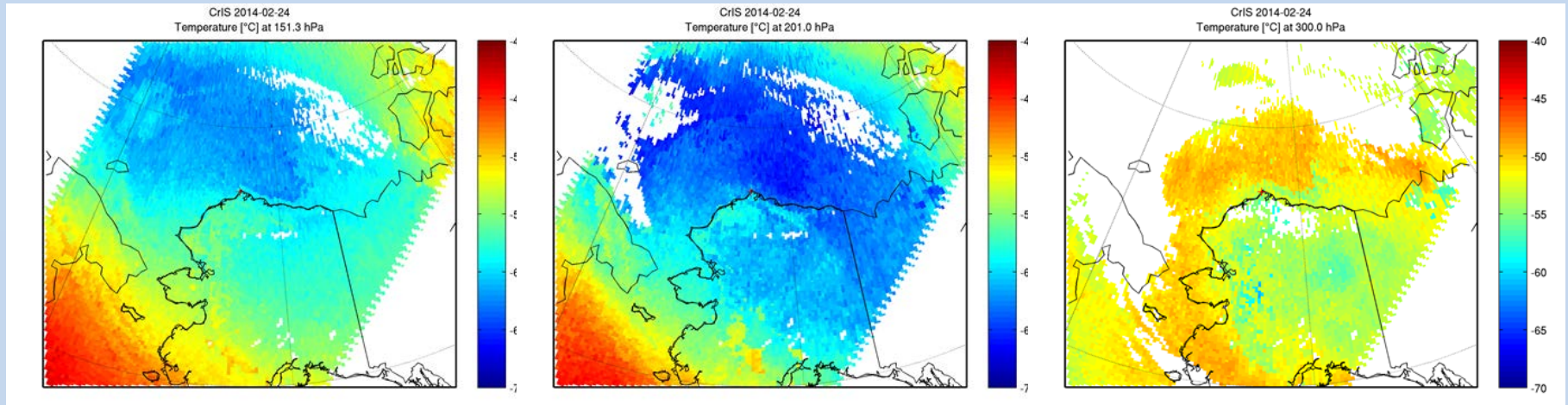


Fig.1. Cold air aloft shown in CrIS sounding data

Prediction of cold air aloft (below -60C) is critical for the Alaska aviation industry. Cold air aloft over the northern coastal region of Alaska on February 24, 2014 was captured by CrIS sounding data. CrIS sounding data show that the vertical extent of the cold air over Barrow is from 250 to 150 mb (Fig.1).

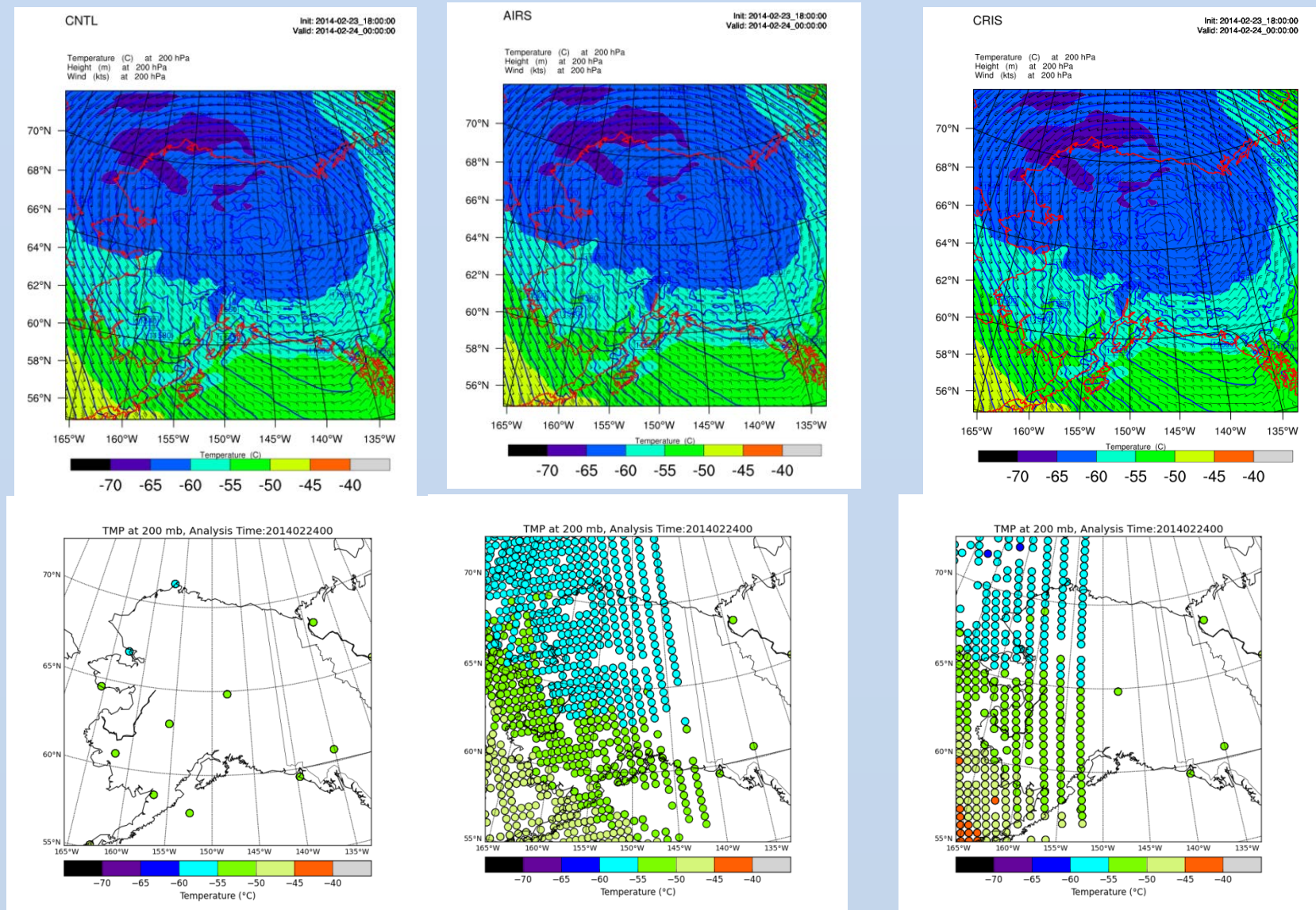


Fig. 2. Above three panels show the initial conditions at 2014022400. They are outputs of WRF run at 2014022318. Bottom three panels are observations from conventional, AIRS and CrIS sounder profiles at 200 mb level.

CNTL

AIRS profile

CrIS profile

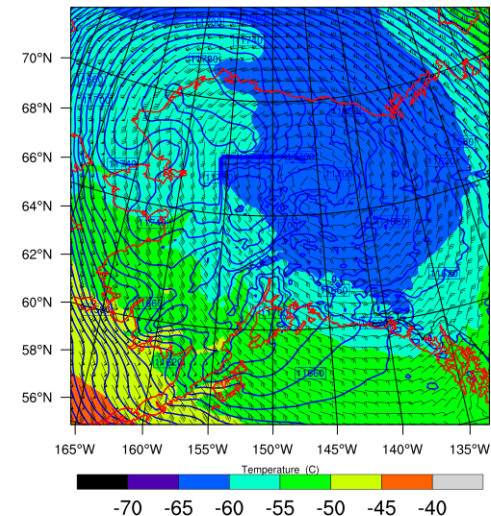
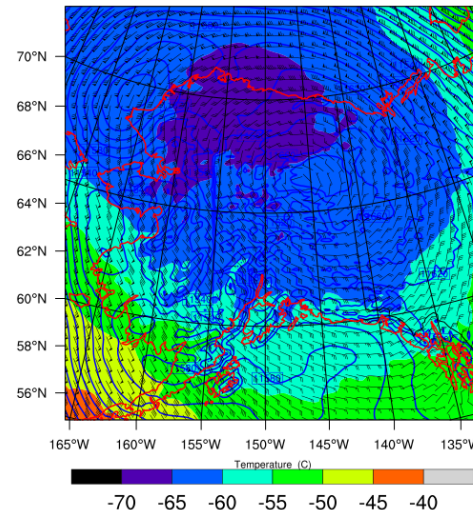
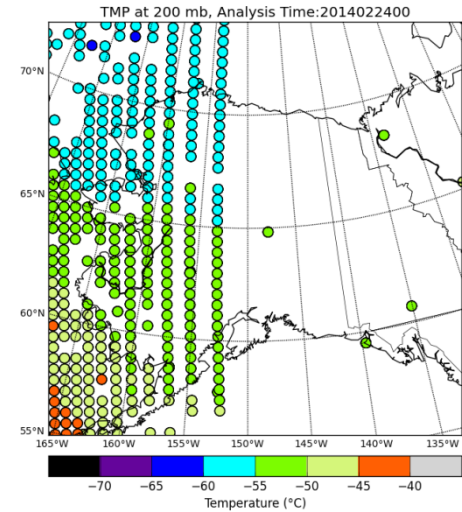
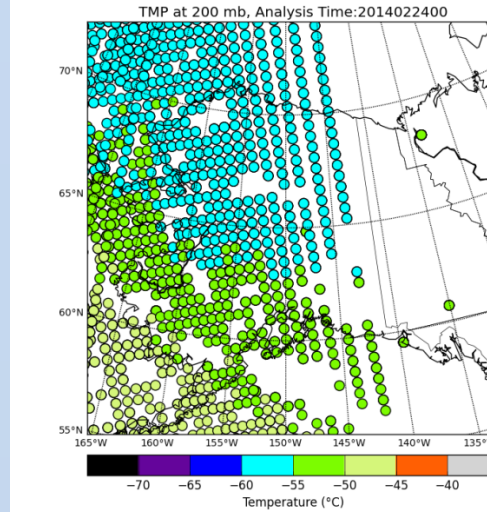
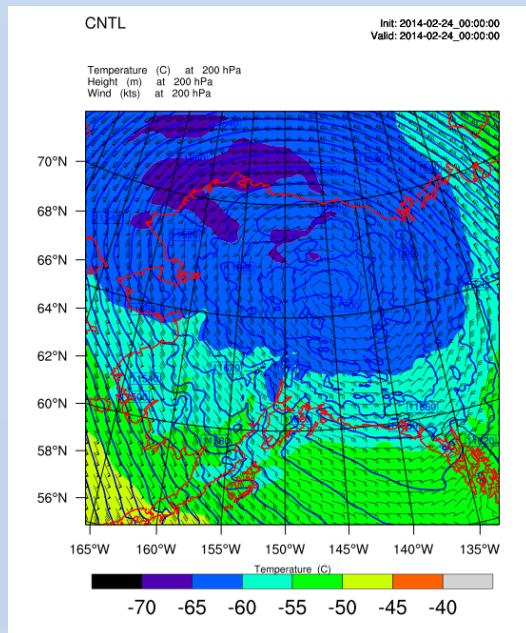
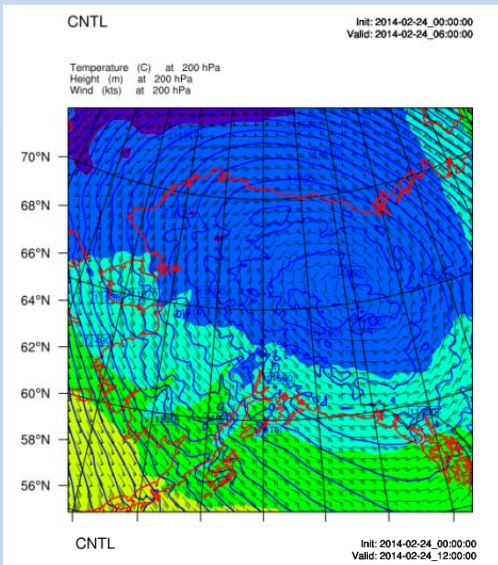


Fig.3. Both AIRS and CrIS sounder profile DAS change initial conditions, but with reverse direction: AIRS strengths the cold air, whereas CrIS weakens the cold air.

6-hour



12-hour

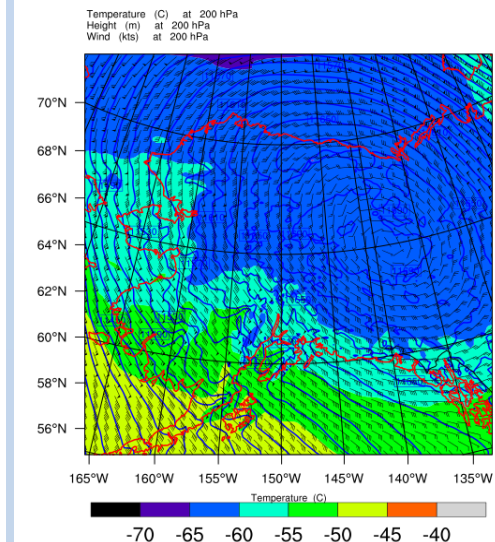
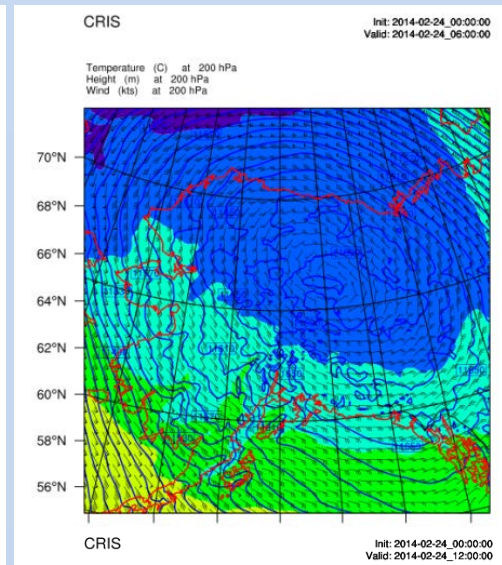
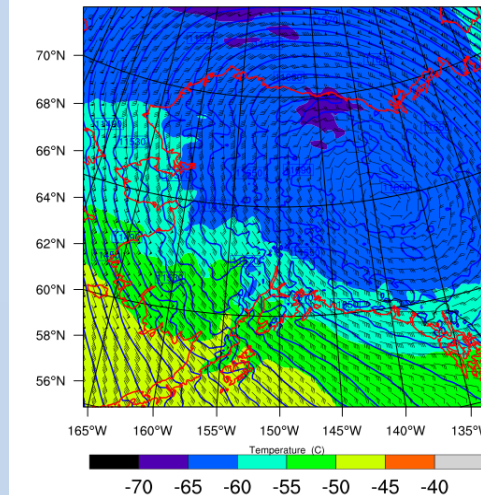
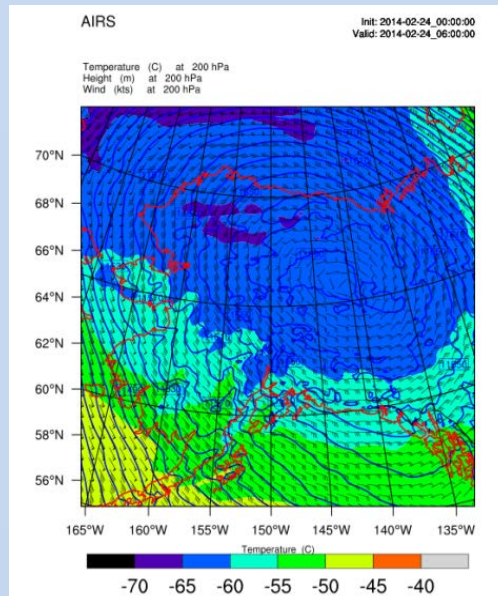
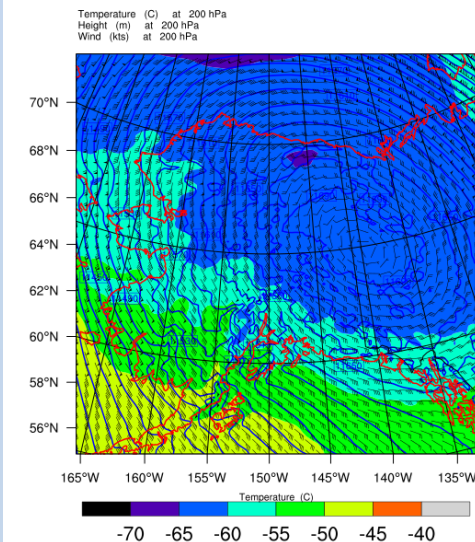


Fig.4. 6-hour (top panels) and 12-hour (bottom panels) forecasts at 200mb. Basically, outputs from three different modes are similar. Only some areas show different. The impact is localized and time-dependent.

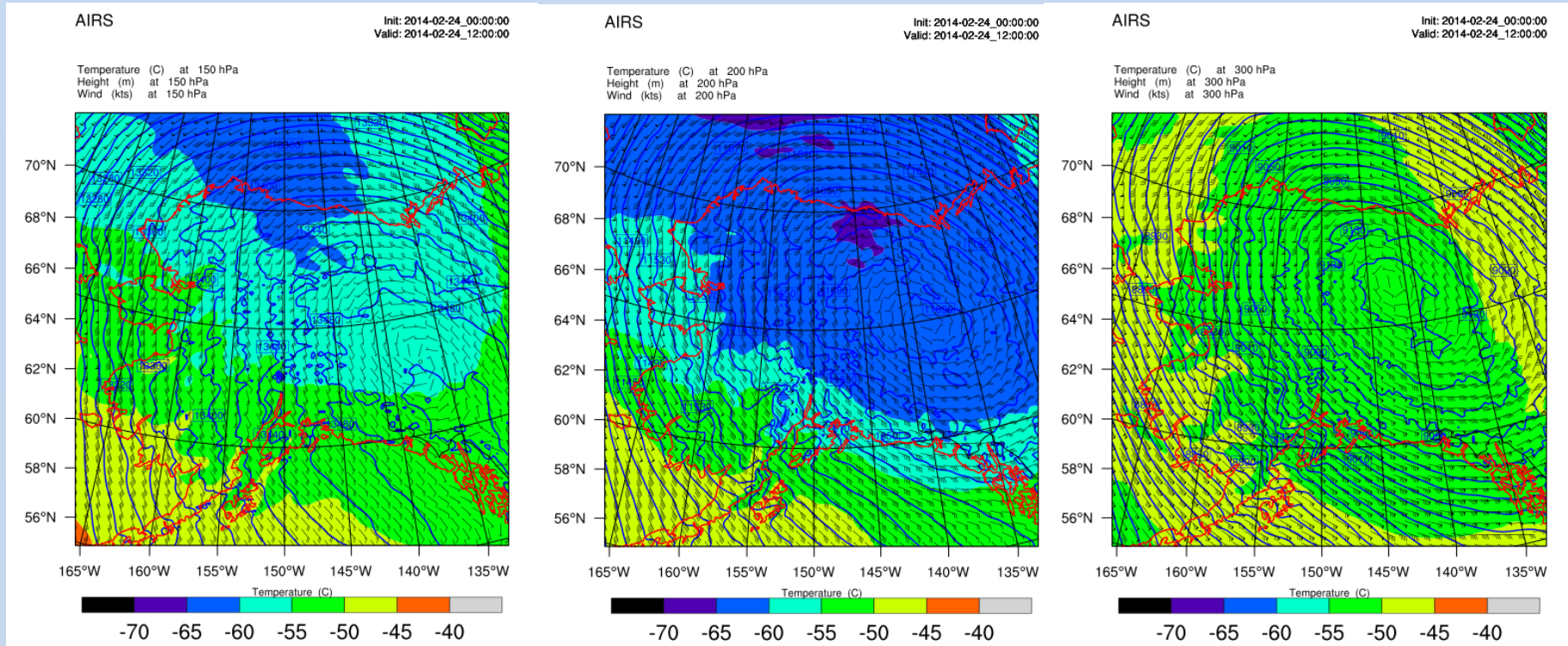


Fig. 5. 12-hour forecast with AIRS profile 3D-Var GSI data assimilation. Three panels show cold air mass from 300 to 150 mbar over northern coastal region of Alaska.

This cold air mass was predicted in the 12-hour forecast by GINA-WRF with AIRS profile data assimilation at analysis time 2014022400. The horizontal extent of the cold air mass predicted in the 12-hour forecast matches the CrIS sounding data very well at every pressure level (Fig.1).

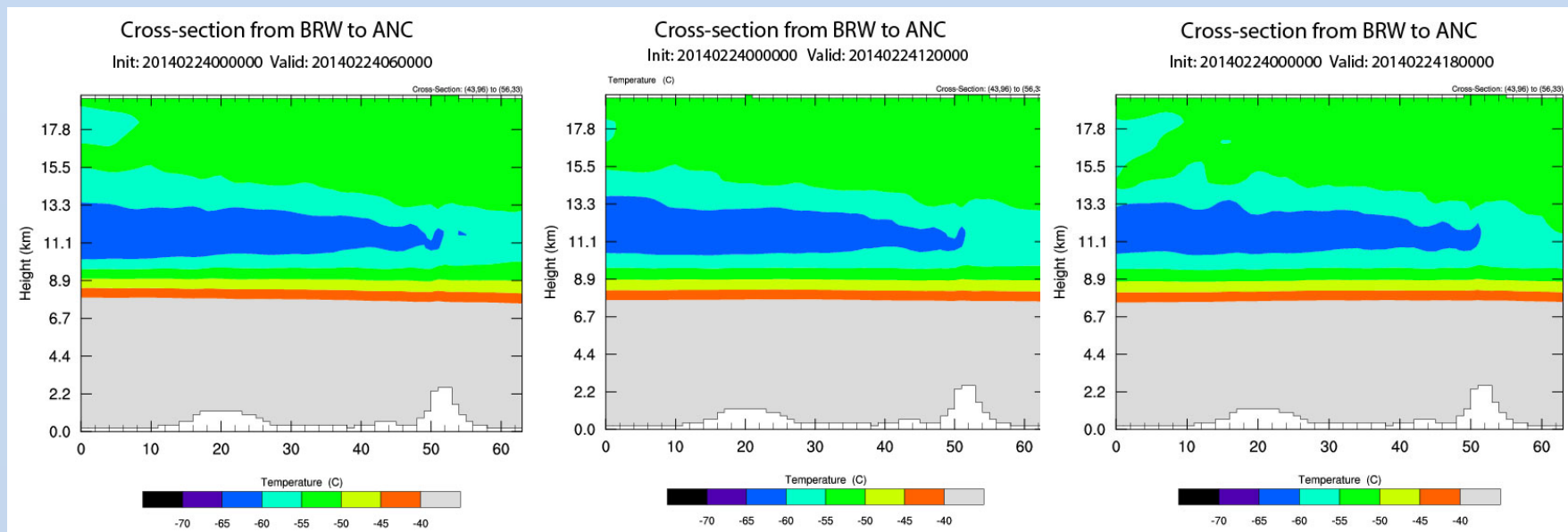


Fig. 6. Cross section views from Barrow to Anchorage of forecasts at analysis time 2014022400.

The 6, 12, and 18-hour forecasts at analysis time 2014022400 (Fig.6) show that the cold air mass hangs over the flight line from Barrow to Anchorage all day long. The vertical extent of the cold air mass over Barrow is from around 9.7 to 13.3 km, which is about 250 to 150 mb. The comparison of CrIS sounding data (Fig.1) to the 12-hour forecast (Fig.6) indicates that the GINA-WRF model with AIRS profile data assimilation can predict the critical phenomena.

Results-monthly statistics

Root-mean-square error (RMSE): measures the differences between values predicted by a model and the values actually observed.

RMSE ratio: is defined as RMSE of a DA run divided by the RMSE of the control run.

An RMSE ratio < 1 indicates that the DA run improves the analysis or forecast.

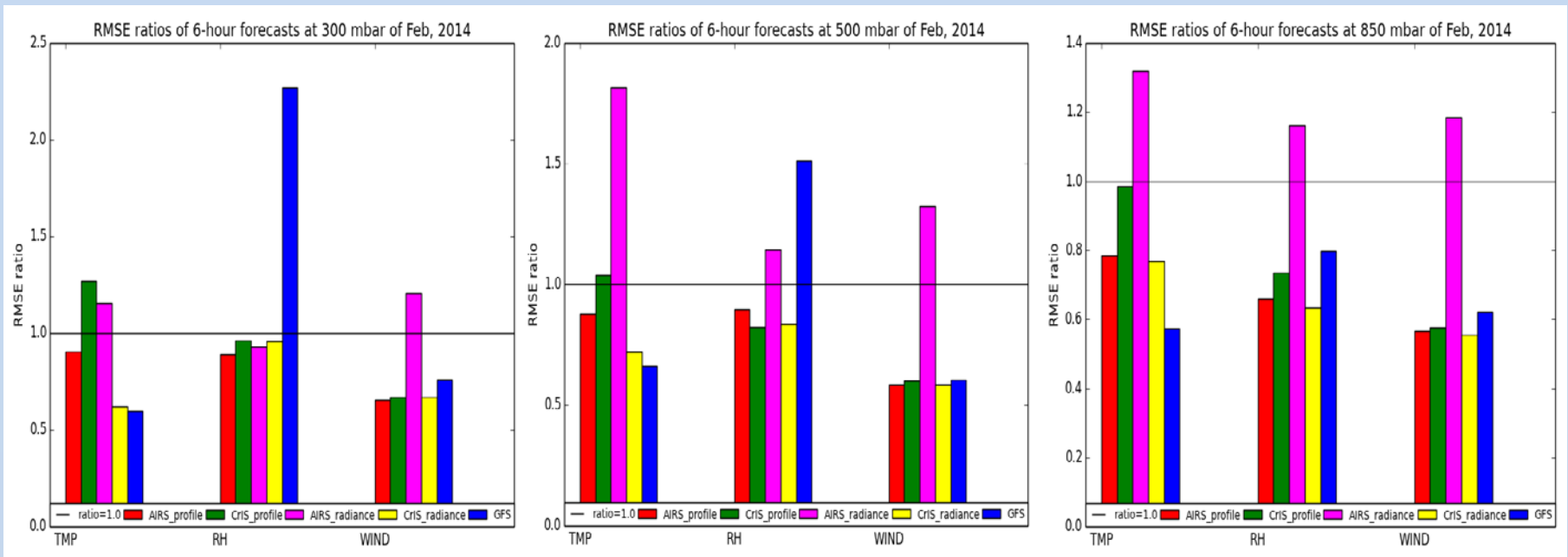


Figure 7. Three variables analyses RMSE ratios for Feb, 2014

The GFS RMSE ratio (Blue) indicates the relative humidity is less accurate than the control run results, although the temperature and wind are more accurate than the control run results. The grid resolution of GFS (0.5 degree) is too coarse for regional weather forecasting.

The median temperature, relative humidity, and wind speed RMSE ratios are 0.90, 0.89 and 0.65 for the AIRS profile DA (Red) and 0.77, 0.83 and 0.67 for CrIS radiance DA (Yellow), respectively. Figure 7 shows that both the AIRS profile and CrIS radiance DA schemes improve the analyses of these three variables at all pressure levels, whereas the AIRS radiance DA does not improve the analyses.

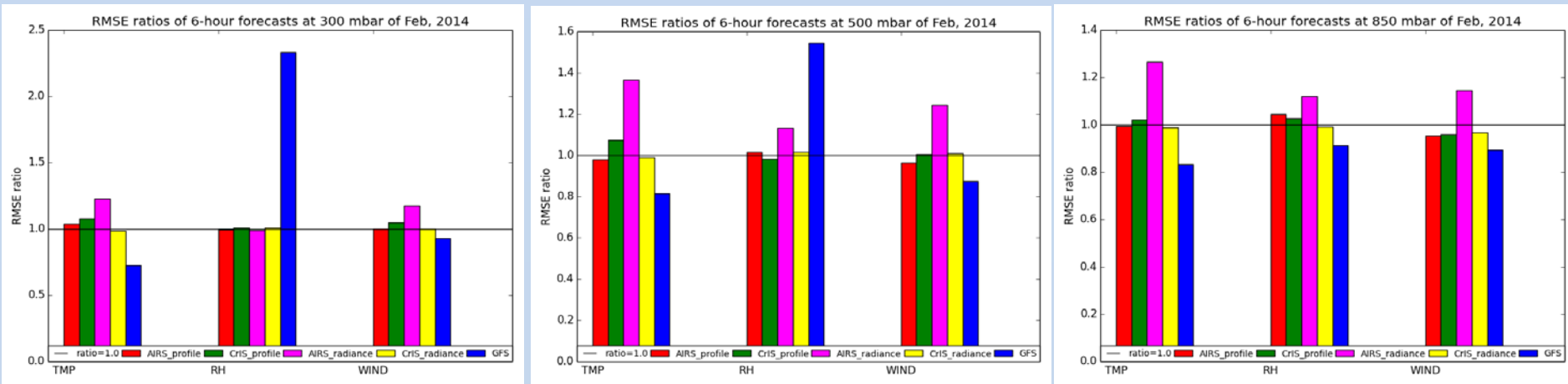


Fig. 8. Three variables 6-hour forecasts RMSE ratios for Feb, 2014

AIRS profile (Red) and CrIS radiance (Yellow) DAs produce smaller RMSEs than the control run. In contrast, the AIRS radiance DA produces even greater RMSE values than the control run. The possible reason for worse performance could attribute to quality control flags in the radiance data.

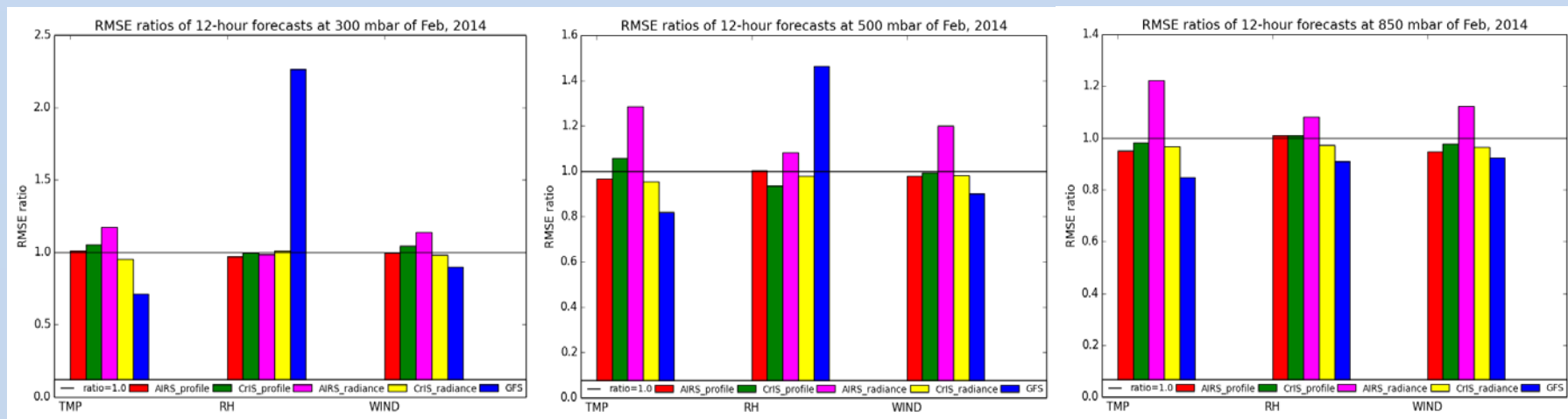


Figure 9. Three variables 12-hour forecasts RMSE ratio for Feb. 2014

12-hour forecasts at three pressure levels from different modes also show that AIRS profile (Red) and CrIS radiance (Yellow) DA runs have better performance than control run.

Conclusions

- 1. GINA-WRF with AIRS profile DA can accurately forecast cold air aloft over Alaska region.
- 2. AIRS profile and CrIS radiance data assimilation improve the analyses of the GINA-WRF. They also improve the forecast, but the improvement is localized and time-dependent.

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Future investigation

- Realize a 4D-Var data assimilation scheme for the GINA-WRF.
- Assimilation Tropospheric Airborne Meteorological Data Reporting(TAMDAR) data.

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